

Overt vs Non-overt Digital Cognitive Metrics
and MRI Brain Measures in The i3C Consortium

A-6708

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Across three digital neuropsychological (NP) tests, slower *"think-time"* and *"ink-time"* tracked with reduced brain volume and greater white matter hyperintensities. These signals were consistent regardless of which test was used. Digital pen metrics may offer a fast, scalable window into brain health that paper-and-pencil tests can't capture.

INTRODUCTION		METHODS																								
- Digital NP tests decompose into two discrete, automatically-timed responses: non-overt "think-time"→ planning/pauses between strokes overt "ink-time" → time/velocity producing stroke - Companion work (Parts 1–2) linked slower think/ink-time to worse cognitive performance, higher ASCVD risk, and elevated serum inflammation/neurodegeneration markers. Objective: Examine relations between digital think-/ink-time metrics and MRI measures of gray matter volume, white matter volume, and white matter hyperintensities (WMH).		Figure 1. Study design and participant flow, from the i3C cohort through digital testing to MRI correlation analysis. <pre>graph TD; A["i3C Consortium cohort n=477 · mean age 55.7 ± 7.7 62% female · 64% White"] --> B["Research MRI (n=241–247) GM · WM volume · WMH"]; B --> C["Cancellation Rowan · visual search"]; B --> D["Trail Making B Linus dTrB"]; B --> E["Clock Drawing Linus dCDT"]; C --> F["Digital metrics extracted think-time · ink-time · placement"]; D --> F; E --> F; F --> G["Partial correlations · p < 0.010 adj. age, education, sex, race"];</pre> Three digital tests: Rowan Cancellation — correct hits; think-time (between circles); ink-time (time circling). Linus dTrB (Trail Making B) — total time; think-time (pause inside circles); ink-time (pen-stroke velocity). Linus dCDT (Clock Drawing) — think-time (between strokes); ink-time (stroke production); component placement (number/hand accuracy). MRI outcomes: intact gray matter volume, white matter volume, WMH.																								
RESULTS		CONCLUSION																								
dTrB ink-time (stroke velocity) → faster velocity associated with more robust white matter ($r = +0.183$, $p < 0.003$) and gray matter ($r = +0.165$, $p < 0.007$). <i>Strongest and only finding spanning both tissue types.</i> Cancellation ink-time → slower ink-time associated with reduced white matter volume ($r = -0.186$, $p < 0.003$). dTrB think-time → slower think-time associated with reduced white matter volume ($r = -0.169$, $p < 0.006$). dCDT component placement → Command linked to WMH ($r = +0.170$, $p < 0.008$); Copy linked to gray matter volume ($r = -0.171$, $p < 0.007$). <i>White matter volume was the most consistently implicated MRI measure; effects were modest ($r \approx 0.17$–0.19) but coherent across all three tests.</i>		Figure 2. Digital neuropsychological metrics relate to brain structure, with white matter volume the most frequent correlate. <table><tr><th>Metric</th><th>Partial correlation coefficient (r)</th><th>p-value</th></tr><tr><td>dTrB · ink-time (velocity) white matter volume</td><td>+0.183</td><td>p<.003</td></tr><tr><td>dCDT-Command · placement white matter hyperintensities</td><td>+0.170</td><td>p<.008</td></tr><tr><td>dTrB · ink-time (velocity) gray matter volume</td><td>+0.165</td><td>p<.007</td></tr><tr><td>dTrB · think-time white matter volume</td><td>-0.169</td><td>p<.006</td></tr><tr><td>dCDT-Copy · placement gray matter volume</td><td>-0.171</td><td>p<.007</td></tr><tr><td>Cancellation · ink-time white matter volume</td><td>-0.186</td><td>p<.003</td></tr></table> <i>For volume measures, positive r = healthier brain; for WMH, positive r = greater damage.</i>		Metric	Partial correlation coefficient (r)	p-value	dTrB · ink-time (velocity) white matter volume	+0.183	p<.003	dCDT-Command · placement white matter hyperintensities	+0.170	p<.008	dTrB · ink-time (velocity) gray matter volume	+0.165	p<.007	dTrB · think-time white matter volume	-0.169	p<.006	dCDT-Copy · placement gray matter volume	-0.171	p<.007	Cancellation · ink-time white matter volume	-0.186	p<.003	- Discrete digital pen metrics relate to underlying brain structure, with white matter integrity the most consistent correlate of think-/ink-time. - The signal is test-agnostic appearing across cancellation, trail-making, and clock-drawing, suggesting think-/ink-time capture a general, transferable construct. - Digital tests are administration-efficient and measure discrete time-based behavior invisible to paper/pencil testing.	
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